Projections of Extended Formulations for the Asymmetric Travelling Salesman Problem

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Abstract

Given a loop-free directed graph $G=(V,A)$ where $V=\{1,\ldots,n\}$ and costs c_{ij} for each arc $(i,j)\in A$ the asymmetric travelling salesman problem (ATSP) is to find a Hamiltonian cycle (tour) contained in the graph. A number of formulations for the ATSP have been proposed and they can be classified into the following two types: A natural formulation and an extended formulation. A natural formulation only contains arc variables that indicate whether or not to include arcs in a tour while an extended formulation have extra variables other than arc variables. Various different ATSP formulations, both natural and extended ones, can be found in Langevin, Soumis, and Desrosiers (1990) and Gouveia and Pires (1999).

Recently, Gouveia and Pires (1998, 1999) have proposed a class of extended formulations that contains precedence variables as extra variables. Precedence variables are defined on each pair of nodes to indicate which node in the pair precedes the other in the selected tour under the assumption that a tour starts from a predetermined node. Gouveia and Pires (1999) developed four extended formulations and they characterized the projections of three of the four proposed formulations into the space of natural variables, that is, arc variables. In Gouveia and Pires (1998), they also introduced another extended formulation and provided a conjecture on its projection.

In this paper,. we develop a general proof scheme that helps to characterize the projections of extended formulations with precedence variables into the natural variable space. Based on this scheme we give short proofs on the projections of the three extended formulations and characterize the projections of the other formulation in Gouveia and Pires (1999). We also prove that the conjecture in Gouveia and Pires (1998) is true.

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